NGGPS Physics Plan Overview

James Doyle (NRL)
Bill Kuo (NCAR)

Thanks to Steve Lord for his help with the physics plan draft.

NGGPS Physics Workshop
27-29 January 2015

- The workshop focused on four topics:
  - Cloud microphysics, especially ice and mixed-phase processes
  - Sub-grid heterogeneity across a range of model resolutions
  - Uncertainties associated with physical parameterization of moist processes, commonly referred to as stochastic physics
  - Interactions of turbulence, radiation, shallow and deep convection, clouds and microphysics
- Brought together more than 100 U.S. and international scientists
- Organized by Robert Pincus and Jim Doyle

NGGPS Physics Workshop

Overarching Themes

- NGGPS represents a great opportunity and NOAA should make the most of this. “This is no time for small steps. Be bold.”
- Representation of moist processes is a suite of inter-connected pieces, and careful attention is required due to the way the various components interact.
  - More conceptual than technical, i.e. addressing code interfaces is necessary but insufficient.
- No modeling center is capable of undertaking a major development activity in isolation. Value of EMC participation in the scientific community at large.

NGGPS Physics Workshop

Key Conclusions

- Two-moment microphysics with multiple categories of ice habits are ready to be tested and implemented in operational models.
- Treatment of subgrid-scale cloud inhomogeneity linked to subgrid-scale turbulence is needed. Includes “eddy diffusion/mass flux” & “assumed probability distribution/higher order closure” schemes.
- Progress has been made in reducing the explicit sensitivity of parameterizations to model resolution (“scale-aware.”). Greatest success has been in convective parameterizations and assumed-distribution representations of clouds and turbulence. Little evidence that any param. suite is yet suitable for variable-resolution grids.
- The “grey-zone problem”, a result of model horizontal resolution being sufficiently small that processes are partly but not completely resolved, will be with the community for a long time.
- The mesh size of global models is now approaching the size at which meso-scale models have traditionally been run. Time to leverage all the work done in the mesoscale physics community.

NGGPS Physics Team Plan Focus Areas

- Scale aware convective and boundary layer formulations.
  - Address grey zone issues with convection and boundary layer clouds and shallow convection
- Microphysics sophistication
  - Replace Single Moment by Two Moment scheme
- Improved interactions between physical processes
  - e.g. radiation, clouds, microphysics and aerosols
- Physically-based framework for stochastics in ensemble prediction.
  - May be beneficial for the deterministic model as well
- Advanced code structures.
  - Increasing level of complexity that can be added or omitted depending on application. e.g., single Moment and two-moment microphysics schemes.
  - Implementation of NUOPC physics driver including single column physics system consistent with the GFS physics (semi-prognostic?)

NGGPS Physics Team Plan Science Working Groups

1. Convection and Boundary Layer
2. Cloud Microphysics
3. Radiation
4. Gravity Wave and Large-scale Orographic (and non-Orographic) Drag
5. Earth System Surface Fluxes and State

- Each SWG activity needs to be shared and coordinated closely across EMC.

NGGPS Physics Team Plan Short Term Goals

- Host physical parameterization workshop (Done)
- Assess current state-of-the-science with regard to physical parameterizations (Ongoing)
- Leverage the collaborative development with NUOPC/National ESPC for the physical parameterization driver interface with 1-D physics capability
- Establish Test and Evaluation Group (TEG).
  - The TEG will support common processes and will support evaluation to promote uniform and consistent procedures and strategies, scripting, data set development and maintenance, component simulators, general software management procedures and NGGPS “trunk” code management.

NGGPS Physics Team Plan
Long Term Goals

1. Convection and Boundary Layer

A. Purpose

Improve the overall conceptual approach to deep convection and Planetary Boundary Layer (PBL) convection by

- Considering PBL convection and turbulence together
- Introducing scale-awareness in horizontal dimension for deep convection and vertical dimension for PBL (stratiform and shallow convection)

B. Development Activities

a. Deep Convection

b. Vertically unresolved shallow, PBL-originated convection

c. Simplified higher order closure approach for turbulence parameterization, stratiform clouds and shallow convection

d. Scale-awareness in both deep and PBL convection

e. Coordinate with Aerosol SWG for cloud-aerosol interactions

f. Coordinate with Cloud Microphysics SWG on cloud properties and precipitation type

g. Improved prediction of 2m T, q and 10 m winds, gustiness, PBL depth

h. Physically-based framework for stochastics

i. Optimize computational efficiency

NGGPS Physics Team Plan
Long Term Goals

2. Cloud Microphysics

A. Purpose

Improve definition of cloud microphysical content, including cloud properties and precipitation type

B. Development Activities

a. Evaluate impact of Single Moment and Double Moment schemes
b. Add aerosol-aware microphysical processes
c. Diagnostic algorithm for precipitation type at surface
d. Coordinate w/ Aerosol SWG on defining cloud-aerosol interactions
e. Coordinate with Radiation SWG on input to radiation param.
f. Optimize computational efficiency

NGGPS Physics Team Plan Long Term Goals

3. Radiation

A. Purpose

Improve accuracy of radiative processes leading to improved weather and climate forecasts

B. Development Activities

a. Improved cloud macrophysical and microphysical formulations
b. Aerosol interactions
c. Surface radiation balance
c. Improved diagnostics for long-wave and short-wave radiation balance
e. Improved spectroscopy as basis for radiation band modeling
f. Optimize computational efficiency

NGGPS Physics Team Plan Long Term Goals

4. Gravity Waves and Large-scale Orographic (and non-Orographic) Drag

A. Purpose

Improve representation of gravity wave drag and orographic drag

B. Development Activities

a. Improve model performance in upper stratosphere and mesosphere (will also improve data assimilation in entire vertical column)
b. Develop non-orographic and non-stationary gravity wave drag
c. Scale-aware orographic drag formulation
d. Gravity wave physics that is adaptable to variable horizontal and vertical resolutions

NGGPS Physics Team Plan Long Term Goals

5. Earth System Surface Fluxes and State

A. Purpose

Improve representation of surface fluxes from all earth domains (land, ocean, sea ice) and the near-surface state of each domain

B. Development Activities

a. Improved parameterized of surface fluxes to and from atmosphere over all domains, including dependencies on wind speed, fetch, vegetation and surface roughness, terrestrial as well as marine (e.g. the effect of ocean waves)
b. Improved skin temperature for all domains (via interaction with the land-surface, and with the upper ocean, ocean mixed layer and below).
c. More complete inventory of surface data from sites over all global domains
d. Maintain SLS compatibility with evolving atmospheric Single-Column Model
e. Improved SST analysis and forecast
f. Coupled hydrological processes such as river flow, ground water, irrigation etc.
g. Improve sea ice physics representation, including radiative, heat, melt-water fluxes

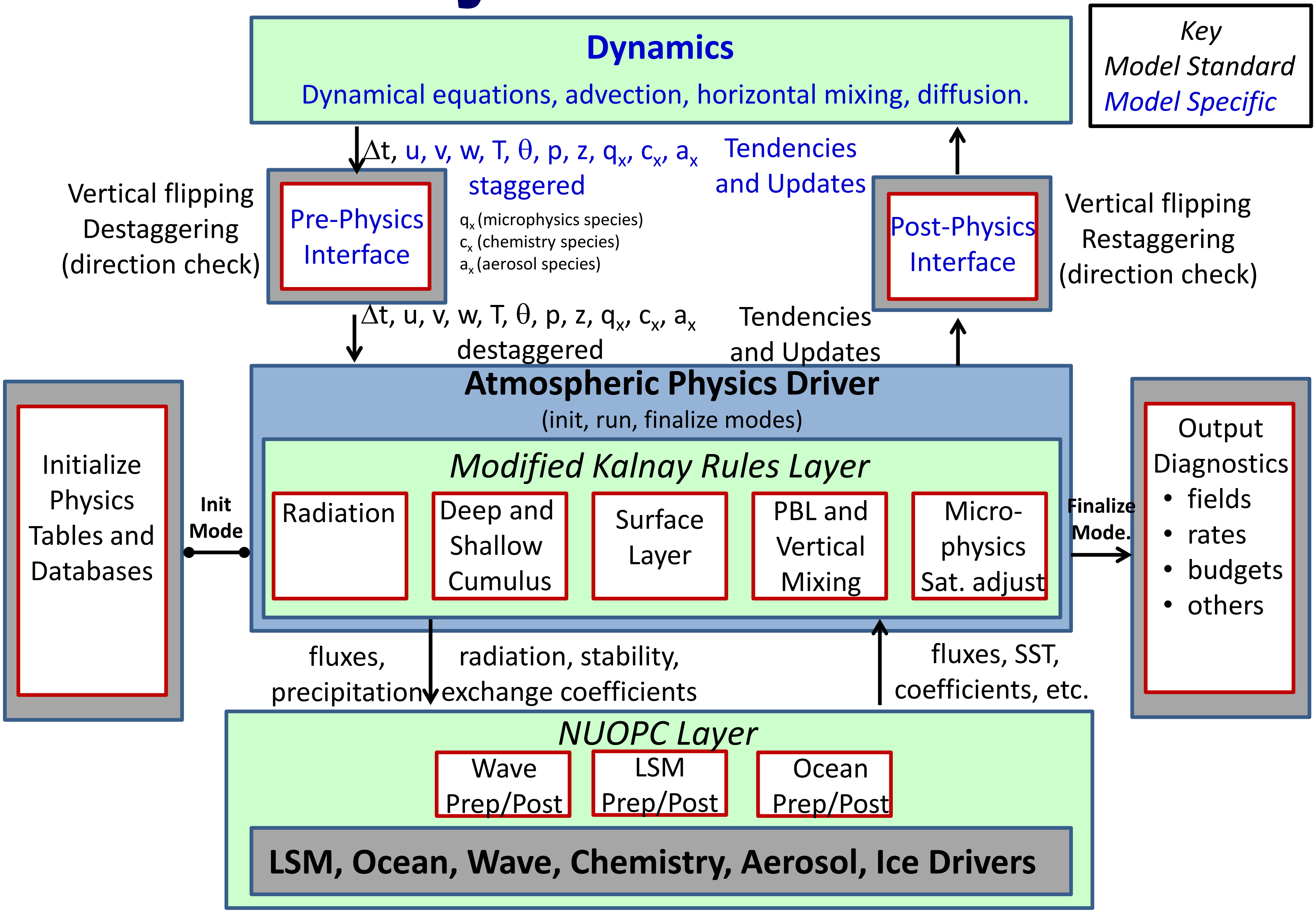
NGGPS Physics Team Plan
Long Term Goals

Development Infrastructure Functions and Resources

Basic development functions for all projects include:

- Executing jobs, including scripting development, disk management, job coordination, monitoring and prioritization;
- Code management and coordination between all projects;
- Diagnostics development and code maintenance, including EMC standard codes and newly developed codes;
- Development and maintenance of component simulators such as a SCM and SLS; and
- Verification, including development and integration of new metrics

NUOPC Physics Driver Schematic



Improving Land Model in NCEP CFS

- **Name and Organization:** **Fei Chen – NCAR/RAL**
- **Project Title: Improving the NCEP Climate Forecast System (CFS) through Enhancing the Representation of Soil-Hydrology-Vegetation Interactions**
- **Objective(s): Incorporate Noah/MP into CFSv2 to enhance the representation of the soil –hydrology-vegetation interactions**
- **Deliverable(s): Coupled CFSv2 with the latest version of the community Noah-MP land surface models**
- **Collaborators: Co-I: Michael Barlage (NCAR); Co-PI: Zong-Liang Yang (UT-Austin) Co-PI: Michael Ek, Co-I: Rongqian Yang and Jesse Meng (NCEP)**

Cloud and Boundary Layer CPT

- **Name and Organization:** **Jongil Han and Ruiyu Sun (NCEP/EMC)**
  Ming Zhao and Chris Golaz (GFDL)
  Chris Bretherton (U. Washington)
  J. Teixeira (NASA/JPL)
- **Project Title:** **CPT to Improve Cloud and Boundary Layer Processes in GFS/CFS**
- **Objective(s):** **Improve fidelity of cloud and boundary-layer processes in GFS/CFS and reduce cloud-related radiative flux biases**
- **Deliverable(s):** **Eddy-Diffusion Mass-Flux (EDMF) parameterization of moist boundary layer turbulence and shallow cumulus in GFS/CFS coupled to improved parameterizations of cloud microphysics and subgrid variability.**
- **Collaborators:** **Marcin Witek (JPL), Chris Jones and Peter Blossey (UW), Krueger and Lu CPTs.**

Unified Gravity Wave Physics

- **Name and Organization:** **Tim Fuller-Rowell, University of Colorado**
- **Project Title*:*** **Integrating unified gravity wave physics into the next generation global prediction system**
- **Objectives:** **Vertically extended configurations of GFS models across the stratopause have the potential to improve longer range 1-4 week terrestrial and space weather predictions; the stratosphere and upper level domains need more sophisticated representation of sub-grid scale physics of unresolved waves to match climatology and observations; non-orographic gravity wave (GW) schemes will improve dynamics, mixing and transport, and as expected they can affect the troposphere-stratosphere coupling and improve predictors of AO and NAO; GW-controlled middle atmosphere circulation also impacts propagation of tides into the thermosphere impacting space weather forecasts.**
- **Deliverables:** **A unified gravity wave parameterization that can be applied to a range of extended GFS models and future NGGPS configurations (including the whole atmosphere L150); a resolution sensitive and adaptable GW scheme. The outcome will be improved model dynamics, transport and mixing for global terrestrial and space weather forecasts.**
- **Co-Is and Collaborators:** **V. Yudin, H. Wang, J. Alpert and R. Akmaev.**

Improving Turbulence and Cloud Processes

- **Name and Organization:** Steven Krueger - U. Utah
  Shrinivas Moorthi - EMC/NCEP
  Robert Pincus – U. Colorado
  David Randall – CSU
  Peter Bogenschutz - NCAR
- **Project Title:** A CPT for Improving Turbulence and Cloud Processes in the NCEP Global Models
- **Objective(s):** Install an integrated, self-consistent description of turbulence, clouds, deep convection, and the interactions between clouds and radiative and microphysical processes
- **Deliverable(s):** Implement a PDF-based SGS turbulence and cloudiness scheme, a cumulus parameterization that scales continuously between simulating individual clouds and conventional parameterization of deep convection, and an improved representation of the interactions of clouds, radiation, and microphysics
- **Collaborators:** Alexei Belochitski and Fanglin Yang (EMC)

Accelerated Implementation of Scale-aware Physics into NEMS

- **Name and Organization:** Shrinivas Moorthi, Yu-Tai Hou - EMC/NCEP
  Steven Krueger - U. Utah
  Donifan Barahona - NASA/GSFC/GMAO

- **Project Title:** Accelerated Implementation of Scale-aware Physics into NEMS

- **Objective(s):** To accelerate the implementation of scale aware physics in Krueger CPT and Lu CPT funded by NOAA/CPO via NCEP/CTB

- **Deliverable(s):** Implement Morrison microphysics (from GMAO's GEOS model) and Chikra-Sugiyama convection with Arakawa-Wu extension into the NOAA Environmental Modeling System physics package as options and test/evaluate

- **Collaborators:** David Randall, Donald Dazlich (CSU), Robert Pincus(ESRL/CU), Sarah Lu (SUNY), Alexei Belochitski, Anning Cheng, Fanglin Yang (EMC), Arlindo DaSilva (GSFC/GMAO)

Scale-aware Stochastic Convection

- **Name and Organization:** Georg A. Grell (NOAA/ESRL/GSD)
  Jian-Wen Bao (NOAA/ESRL/PSD)
- **Project Title:** Further Testing and Evaluation of a Scale-Aware Stochastic Convection Parameterization in NOAA's Next Generation Global Prediction System
- **Objective(s):** Implement scale-aware GF convective parameterization into HWRF and later into NGGPS
- **Deliverable(s):** Evaluated working version of GF in HWRF and publication describing implementation and evaluation
- **Collaborators:** Vijay Tallapragada (NOAA/EMC)

Evaluation of Advanced Microphysics Schemes

- **Name and Organization:** Jian-Wen Bao and Robert Cifelli
  NOAA/ESRL/PSD
- **Project Title:** Evaluation and Adaptation of Advanced Microphysics Schemes in NOAA's Next Generation Global Prediction System Using NOAA-HMT Observations
- **Objective(s):** Advanced bulk microphysics schemes are compared with each other and observations to facilitate the selection of a computationally efficient and physically sufficient scheme for the NGGPS
- **Deliverable(s):** Analysis of microphysics budgetary evaluation and results of comparing model simulations of selected NOAA-HMT cases with observations
- **Collaborators:** Brad Ferrier and Eric Aligo (NOAA/NCEP/EMC)
  Sara Michelson and Evelyn Grell (NOAA/ESRL/PSD)